

Regulation-relevant network science and engineering

Both the Internet revolution and the Wireless revolution have moved beyond a purely technical domain. They are core parts of the national infrastructure and billions of dollars are spent on them every year. However, these are interesting times in that the Internet and Wireless communication are subject to *both* radical *technological advancements* and radical *regulatory developments*. Unfortunately, the current structure of federal institutions is not able to deal with radical developments in both simultaneously. Policy makers are asked to write and implement forward-looking regulations that reflect the collective will of the citizenry and are likely to be effective in the real world. Political processes can help understand the will of the public but they must be complemented with sound science and an understanding of the engineering trade-offs.

Consider the Internet first. It has revolutionary possibilities to tap the creativity of the citizenry and enable new forms of community engagement and collective action. At the same time, economic incentives play a major role. However, the network protocols were originally designed without attention to such incentives. Consequently, the Internet is faced with severe market failures and inefficiencies that can and should be corrected. Yet, the network neutrality debate is politically charged. Both the two extremes (full neutrality and zero neutrality) are undesirable for economic or public-good reasons. Research is essential to understand the trade-offs involved so that middle-ground approaches can be found. Similarly, the poor level of security in the Internet results in large part from the absence of proper incentives for users to protect their computers. The trade-offs of mechanisms (e.g. certification agencies, insurance schemes, due care or liability policies, rebates on access fees for protected computers) to provide such incentives must be understood before good policies can be formulated.

The issues in the wireless domain are even more stark. For decades now, the paradigm has been that users required a license to operate a wireless system and that any piece of wireless equipment was restricted to a few spectrum bands wherein they obeyed fixed protocols. This was how interference was precluded. Advancements in circuits driven by Moore's law has brought us to the brink of radio equipment that are frequency-agile and "cognitive" in the protocols that they follow. This promises to have a revolutionary impact that dovetails with the impact of the Internet and personal computing. It is now technically conceivable that two people in their garage will be able to roll out their own wireless service and have a reasonable chance of growing organically as they grow their user base without disrupting other wireless systems. This will enable rapid and creative innovation without holding it hostage to either standards committees or the business plans of the incumbents. Wireless spectrum policy must be reformulated to take this into account and the underlying trade-offs need to be understood in order to do this with a suitably light hand of regulation. The core question is to determine the fundamental limits on the overhead required for regulation the same way that we have such guidance from Shannon's theory for spectral efficiency.

For both the Internet and Wireless systems, the main federal agency relevant to policy-making is the FCC. How can it get access to the trade-offs relevant to making policy decisions? The traditional approach is to just call together a panel from the National Academy of Sciences and the National Academy of Engineering and asking them for a report of our current understanding. The problem is that we do not have the body of research results required to provide that understanding. So where is that basic research going to come from? Who is going to pay for it?

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The challenge is that both the Internet and wireless revolutions will have their impact in part due to enabling "creative destruction" as new business models and new ways of doing things emerge. Thus, existing industry cannot be trusted to take the lead in doing this sort of research since incumbent players will be accused of taking a side in favor of their own economic interests. A similar criticism applies to startup companies. Venture capital firms are less likely to invest in startups pursuing technologies that can only be deployed if the regulatory environment changes. Even if they do, the current patent system in the United States would encourage them to try to get key patents that would then lead incumbents to viscerally oppose any such regulatory change since they would be locked-out of benefiting from it.

Government research labs could in principle take the lead in developing the relevant understanding. The problem comes in finding people --- the past structure of science and engineering education in the United States has not produced many people who are simultaneously technically trained and have an appreciation for the kinds of policy trade-offs involved. Therefore, these research problems are best handled within Academia where commercial interests are not driving the choice of questions and students can be trained in a way to appreciate these new kinds of trade-offs.

The question is then which agency or agencies should be funding the work that needs to be done. In the past, DARPA has done a good job of taking the lead in exploring focused new areas. However, the DARPA culture tends to be deliverable-oriented and has rarely funded the kind of basic theoretical research required here. Other agencies might also be uncomfortable with having regulation-oriented basic research coming out of DARPA --- would it be perceived to favor military interests over civilian ones? The National Science Foundation has an excellent track record of funding unbiased theoretical research. The challenge is that the existing peer-review culture is quite conservative in today's Malthusian funding climate. This could be remedied by giving certain new pots of money in the name of federal agencies like the FCC. This money could be accessed by NSF program managers only to fund projects that help provide the basic scientific and engineering foundations for the regulatory questions likely to be relevant to that agency in the future.